TTY Forum Test Results Summary

Technology: CDMA "No-Gain" Solution

Contribution Date: 99.01.26

Contribution Number: 99.01.26.09

Contributing Company: Lucent

Summary: This solution presented to the forum offers the most encouraging news regarding the "Voice based" solution. The method used in the no gain solution is an enhanced version of the TTY/TDD receiver / repeater concept originally presented by R. Haimi-Cohen of Phillips Consumer Communications.

TITLE:

Simulation of a Robust In-Band Transmission System for TTY/TDD Signals Using an Inter-Operable Modification of the IS-127 Standard Speech Coder

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ABSTRACT:

A robust system for transmitting 45.45 BPS Baudot-Encoded TTY/TDD signals using an inter-operable modification of the IS-127 EVRC speech coder is presented. The methods used combine an enhanced version of the TTY/TDD Receiver/Repeater concept originally presented by R. Haimi-Cohen of Phillips Consumer Communications, some minor modifications of the EVRC algorithms, and a new approach that embeds redundant TTY/TDD information in the EVRC data packets without affecting inter-operability with unmodified EVRC implementations. Results in terms of TTY character error rate (CER) are presented for clean channel conditions and for a 2% FER channel.

RECOMMENDATION:

Informational.

Supports VCO/HCO

TURBO CODE

Copyright Statement:

Notice:

INTRODUCTION:

In the November, 1998 task group meeting, we had presented a contribution demonstrating the performance of a simulation of the PCC proposed TTY/TDD Receiver/Repeater algorithm for robustly transmitting Baudot TTY signals in-band. Those simulation results made use of idealized models of a TTY demodulator and of the CDMA channel. That contribution showed that, in a 2% FER channel, the character error rate (CER) could be reduced from roughly 17% to below 1%. Since that time, we have conducted a number of additional experiments using more realistic rather than idealized simulations for the vocoders, channel and demodulator. The CERs obtained in these new experiments was considerably higher than that obtained in the idealized simulations. For example, for the EVRC, the CER obtained in a 2% FER channel was about 2.5% rather than the less than 1% quoted in our November contribution. On further examination, it was discovered that the best performance obtainable with the EVRC in clear channel conditions (0% FER) was about 1%. Similar results were obtained f r the CDMA-13K vocoder. While the 2.5% CER obtained using the receiver/repeater might be adequate to meet the federal mandate, we discovered an improved method that leverages the same processing required by the receiver/repeater and permits us to achieve significantly better performance in both clear and impaired channel conditions.

A new interoperable solution (the LT-TTY solution] is proposed to yield essentially a 0% CER for clean channel as well as 2% FER channel conditions. The new solution involves some modifications to the EVRC encoder[1] as well as the decoder, but is much more robust in bridging multiple frame erasures and is expected to give good performance even in channels much worse than 2% FER. The LT-TTY solution is completely interoperable with unmodified EVRC systems, and it is recognized that a modified decoder might sometimes have to operate in an environment where the encoder has not been modified. In order to improve performance in these cases, the LT-TTY solution also incorporates the receiver/repeater. In all other cases, the receiver/repeater is present in the decoder but does not operate. Complexity is very low and is approximately the same as that required to implement the receiver/repeater, so the incremental compexity incurred in implementing the LT-TTY solution is minimal. This contribution briefly outlines the results of our experiments with the EVRC and 13K vocoders, describes the new algorithm and the way it is combined with the receiver/repeater and presents results on both clear channel and 2% FER channel conditions for all encoder/decoder combinations.

It is our intention to provide source code for the modified EVRC encoder as well as some useful utilities. The simulation is in the last stages of testing, and should be available in approximately two weeks. Interested parties should contact either of the authors of this contribution to obtain the software and documentation.

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[1] While the new solution was implemented using the EVRC, the principles generalize equally well to all of the currently standardized speech coders for wireless applications.

Table 1: CER Performance in 0% FER Channel

Decoder	Encoder		
	Unmodified	Unmodified (ns off, rate = full)	Modified
Unmodified	1% - ? (see text)	1%	0%
Modified	1% - ? (see text)	1%	0%

Table 2: CER Performance in 2% FER Channel

Decoder	Encoder		
	Unmodified	Unmodified (ns off, rate = full)	Modified
Unmodified	10% - ? (see text)	10%	8.5%
Modified	2.5% -? (see text)	2.5%	0%

CONCLUSION

A totally passive, receiver-only solution for transmitting TTY/TDD signals in-band through the EVRC as presented in the original PCC contribution would be performance limited by the timing jitter introduced by the EVRC's long-term predictor and by the frame erasure handling algorithms specified in the IS-127 standard. An improved solution has been presented that can provide essentially error-free performance in channel conditions much worse than 2%. The proposal also includes the original PCC proposal because (1) it provides an extra level of insurance against the case where the modified terminal must operate with unmodified infrastructure or visa-versa, and (2) many of the operations required to implement the receiver/repeater in the decoder (as proposed) are also required to implement the new solution, so the incremental overhead to implement both is very low.

→ MIP (memory count) may be an issue
will the software upgrade over-load
the vocoder load Page 6 of today
— "New chip" —

2. **Unmodified encoder (noise suppression off, RDA forced to full-rate) - unmodified decoder.** This case is included because the ability to externally control whether or not noise suppression is turned on and to force the RDA to a particular rate is required by the IS-127 specification, and it is known that: (a) Noise suppression may be turned off with very little effect on speech in the forward link (in fact, it may actually improve tandem performance), and (b) some terminals that implement a special connector for TTY (but no other modifications) may be able to sense the presence of something connected to the TTY connector and transmit these commands to the EVRC encoder without modifying their vocoder firmware.

3. **Unmodified encoder (noise suppression on) - modified decoder.** This scenario tests the operation of the receiver/repeater with a completely unmodified transmitter, e.g. the forward link performance of a modified terminal with totally unmodified infrastructure.

4. **Unmodified encoder (noise suppression off, RDA forced to full-rate) - modified decoder.** This scenario tests the operation of the reciever/repeater with a minimally modified transmitter, e.g. the reverse link performance of modified infrastructure with a terminal as described in (2), above.

5. **Modified encoder - Unmodified decoder.** This essentially demonstrates the benefits of disabling the long-term predictor on the encoder, even when used with unmodified decoders.

6. **Modified encoder - Modified decoder.** This tests the operation of the new method, i.e. embedding the Baudot character information in the unused delay bits.

Preliminary results for 0% FER and 2% FER are presented in tables 1 and 2. The results show that the encoder modifications by themselves are sufficient to reduce the CER to 0% for the clean channel condition, even when used with an unmodified EVRC decoder. When coupled with the decoder modifications, the CER remains 0% even for a 2% FER channel. Used only as a receiver/repeater, the proposed solution achieves a CER of 1% in clear channel (no change), but reduces the CER from 10% to 2.5% in a 2% FER channel. Results for cases (1) and (3) above are extremely level dependent – if the signal is sufficiently strong, noise suppression and the RDA have essentially no effect. However, if the signal has been attenuated prior to entering the encoder, performance will be significantly degraded by these modules for cases (1) and (3).

BACKGROUND

A number of sources (including Lucent) have presented CER results for TTY/TDD signals passed through various speech coders under different channel conditions. The industry consensus was that, in clear channel conditions, the speech coder does not constitute a significant impairment to Baudot signals, and that the CER in impaired channel conditions was between 8 and 9 times the FER. This result was consistent with intuition since a Baudot character occupies between 8 and 9 CDMA frames, and if any one of them were to be lost the character would also be lost. Our experiments with both the EVRC and the QCELP-13K vocoders verified that it is possible to obtain 0% CER for a clear channel using the QCELP-13K vocoder, but that the best performance in a clear channel using the EVRC would be slightly more than 1% CER. Further study yielded the understanding that the EVRC's simplified long-term predictor causes as much as a 5 msec. jitter in Baudot pulse duration, which in turn leads to the observed degradation in clear channel CER performance. This supposition was verified by the fact that 0% CER was obtained in a clear channel once the EVRC's long-term predictor was disabled. The other effect noted was that, in the frame following an erasure, there was a lag of about 10 msec before the decoder converged to the correct value if a bit transition had occurred during the erased frame. The duration of this re-convergence interval was closer to 20 msec for the QCELP-13K vocoder, accounting for its significantly worse CER performance in channel impairments.

The original receiver/repeater solution was proposed as a passive receiver-only modification. However, because of the timing jitter introduced by the EVRC's long-term predictor, the best performance obtainable using the original receiver/repeater proposal is limited to about 1% CER in clear channel conditions and about 2.5% CER in a 2% FER channel. On the other hand, if the field of possible solutions is opened up to include low-complexity completely transparent (interoperable) modifications to the encoder as well as the decoder, considerably better results are possible. Particularly, since part of the EVRC's difficulty in transmitting TTY/TDD signals arises from the fact that its long-term predictor is ill-suited to modeling the Baudot waveform, it is apparent that the bits used to convey the long-term prediction information can be put to better use provided that Baudot waveform-containing frames can be uniquely identified to a modified decoder. The LT-TTY solution makes use of the delay bits to convey Baudot characters in frames that contain ONLY Baudot waveforms. Since the adaptive codebook gain is set to zero in these, an un-modified EVRC decoder simply ignores the delay information, rendering this type of approach transparently interoperable with an unmodified EVRC decoder. Moreover, since the adaptive codebook is disabled for Baudot frames, the performance of an unmodified decoder is better when used with a LT-TTY modified encoder than when used with an unmodified EVRC encoder.

HIGH-LEVEL DESCRIPTION OF THE NEW ALGORITHM

The following modifications are made to the EVRC encoder: A Baudot detector is used to distinguish input frames that contain ONLY Baudot waveforms. If Baudot is detected, noise suppression is turned off, the rate decision algorithm (RDA) is forced to encode the packet at Rate 1, the adaptive codebook gain is forced to zero prior to matching, and a "Waiting-for-Baudot" code is inserted into the bits normally used for the pitch lag in the EVRC encoded data packet. The encoder simultaneously encodes the Baudot signal without an adaptive codebook contribution, permitting an unmodified decoder to operate on the packet stream. As long as Baudot is detected, the algorithm demodulates the signal and begins buffering decoded character information until an entire character is decoded, while continuing to transmit packets with zero adaptive codebook gain and the "Waiting-for-Baudot" code inserted into the delay bits. Once an entire character has been decoded from the audio input, the character is then encoded into the pitch delay bits along with a sequence number to uniquely identify the particular character and its instance. The character is then transmitted in the same way in each frame until either the next character is decoded or 9 frames have elapsed. In this way, the decoder has between 8 and 9 opportunities to receive the character and regenerate it, permitting robust detection in channels considerably worse than 2% FER.

On the decoder side, a Baudot detector is used to detect frames containing ONLY Baudot waveforms. If Baudot is detected, the algorithm begins demodulating the Baudot signal and buffering the demodulated output. Simultaneously, it checks for the presence of the combination of zero adaptive codebook gain and the "Waiting-for-Baudot" code in the pitch lag bits to determine whether or not the signal originated from a modified EVRC encoder. If the adaptive codebook gain is not zero but Baudot waveforms are detected, it is assumed that the signal originated with an unmodified encoder and the algorithm operates as a character-based implementation of the receiver/repeater. If the adaptive codebook gain is zero and the "Waiting-for-Baudot" code is present for a requisite number of frames, it is assumed that the signal originated with a modified EVRC encoder and waits to receive the first character and sequence number in the pitch lag bits. In both cases, audio output is muted pending the receipt/demodulation of an entire character, and once demodulated, the character is regenerated at the decoder by an ideal TTY/TDD modulator. Other changes in the decoder resulting from a Baudot detection are that the frame erasure handling and postfilter are disabled for Baudot frames, and the decoder is reinitialized on the first good frame following an erasure, provided the last good frame was a Baudot frame. This last modification reduces the reconvergence interval for the decoder after an erasure and significantly improves the performance of the receiver/repeater.

RESULTS AND DISCUSSION

Six scenarios have been tested:

1. **Unmodified encoder (noise suppression on) - unmodified decoder.** This is the baseline case.

TTY Forum Test Results Summary

Technology: TDMA / AMPS / GSM

Contribution Date: 99.01.26

Contribution Number: 99.01.26.10

Contributing Company: Ericsson

Summary: This contribution reports the results of testing from Ericsson. The testing was done in a lab simulating field environments. A summary of the results are listed on page 16 of this contribution.

The signal strengths used for test were:

- **Analog**
  High Power -80 dBm
  Low Power -95 dBm
- **DAMPS 1900 (TDMA)**
  High Power -75 dBm
  Low Power –95 dBm
- **GSM**
  Medium Power -91 dBm
  Low Power –95 to –103 dbm

The TCER for Analog was no greater than 2.9%.
The TCER for TDMA was no greater than 4.05%.
The TCER for GSM was no greater than 0.54% for High power and 5.61% for Low Power.

For connectivity to the mobile handset device, Ericsson coupled an Ultratec 4425 device to a modified acoustic handset between the TTY and the mobile.

ERICSSON ⧌

TTY/TDD Compatibility Measurements (Preliminary Results)

By

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TDMA & GSM Technology Groups

Research Triangle Park, NC

January 26-27, 1999

TOPICS

- ## TTY / DIGITAL WIRELESS COMPATIBILITY

- ## SYSTEM TEST SETUP

- ## TEST RESULTS
  - ### – ANALOG
  - ### – DIGITAL
  - ### – GSM
- ## CONCLUSIONS

TTY / Digital Wireless Compatibility Issues

- **<u>TTY Compatibility Issues</u>:**
- **Industry Standard for TTY devices**
- **Modulation using FSK Baudot 45.45**
- **Interface to digital wireless**
- **Performance tolerance**

- **<u>Digital Wireless Compatibility Issues</u>:**
- **Digital wireless optimized for voice**
- **Vocoder distorts sinusoids in FSK signaling**
- **Size**
- **Noise and Interruptions**

TTY / Digital Wireless System Test Set Up

- **Conditions:** Controlled Lab environment, stationary test
- **Technology:** AMPS, DAMPS1900, GSM 1900   *TDMA-IS-136*
- **Test Script:** 1) Lober & Walsh Ver 1.1 Copyright 1998
  4000 + random characters
- **Scored:** PCER=number of missed and replaced character
  TCER= Baudot code character shifting

- **Connection:** Ultratec 4425 coupled to Modified acoustic
  handset, between mobile and TTY device

- **Network:** AMPS 800MHz: Commercial Network
  DAMPS 1900MHz: Internal Basestation linked to PBX
  GSM 1900MHz: Commercial Network

DAMPS Mobile Termination Configuration
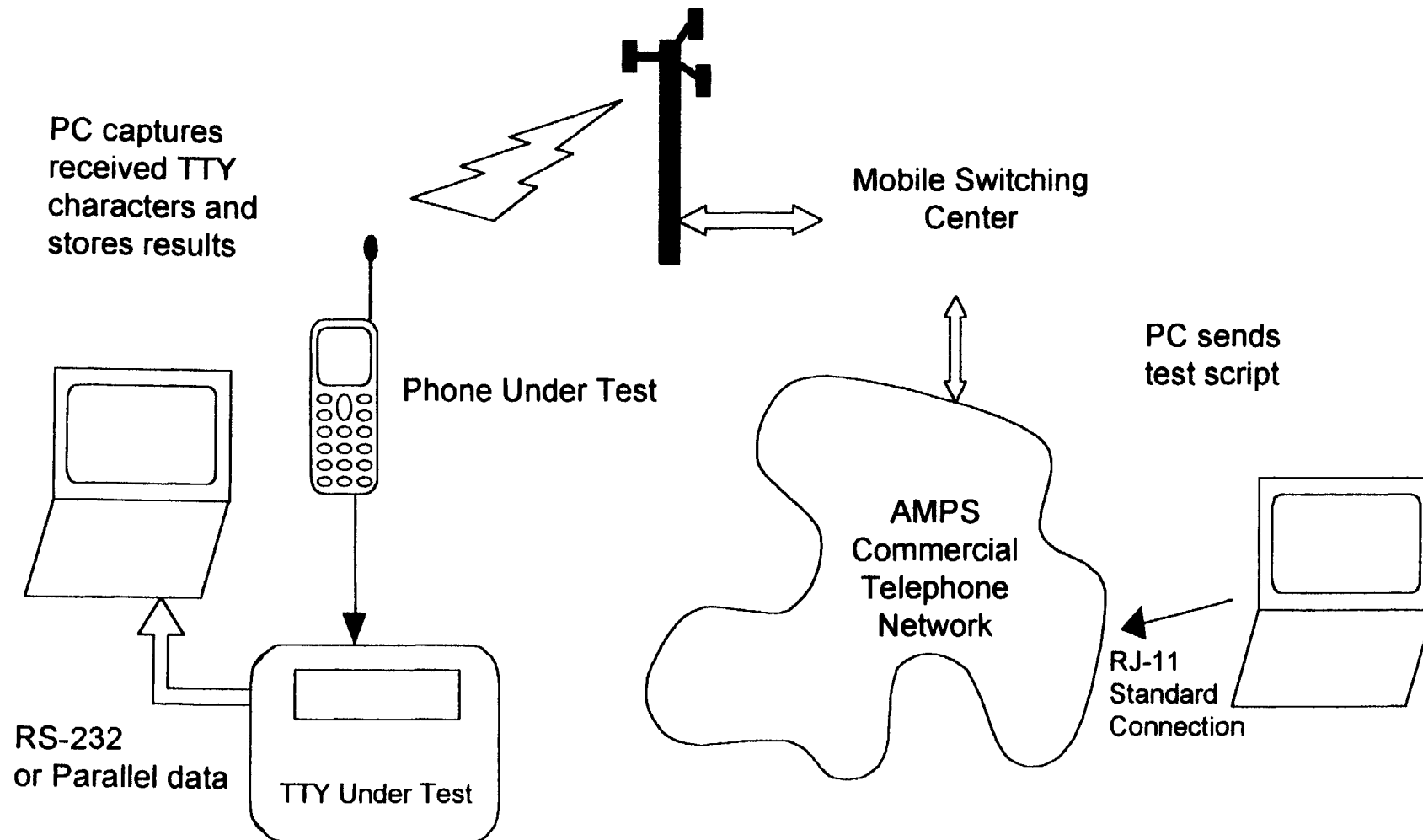
PC captures
received TTY
characters and
stores results

Mobile Switching
Center

Phone Under Test

PC sends
test script

AMPS
Commercial
Telephone
Network

RJ-11
Standard
Connection

RS-232
or Parallel data

TTY Under Test

TTY / Digital Wireless

Test Data and Results

AMPS

Using test script from L&W Version 1.1 Copyright 1998
Device tested: AF778 with Acoustic Coupler

Uplink **HIGH** power (-80dBm)

- Percent Error (PCER)   =   0.78
- Total = 772, Correct 766, Added = 0, Missed = 1, Changed = 5
- Percent Error (TCER) =   0.54
- Total = 1116, Correct 1110, Added = 0, Missed = 1, Changed = 5

Downlink **HIGH** power (-80dBm)

- Percent Error (PCER)   =   0.65
- Total = 772, Correct 767, Added = 27, Missed = 1, Changed = 4
- Percent Error (TCER) =   0.36
- Total = 1119, Correct 1115, Added = 27, Missed = 2, Changed = 2

TTY / Digital Wireless
Test Data and Results
~~AMPS~~
Using test script from L&W Version 1.1 Copyright 1998
Device tested: AF778 with Acoustic Coupler

Uplink LOW power (-95dBm)
- Percent Error (PCER)   =   0.26
- Total = 772, Correct 770, Added = 0, Missed = 0, Changed = 2
- Percent Error (TCER) =   0.18
- Total = 1118, Correct 1116, Added = 0, Missed = 0, Changed = 2

Downlink LOW power (-95dBm)
- Percent Error (PCER)   =   5.18
- Total = 772, Correct 732, Added = 32, Missed = 22, Changed = 18
- Percent Error (TCER) =   2.90
- Total = 1104, Correct 1072, Added = 35, Missed = 25, Changed = 7

DAMPS Mobile Termination Configuration
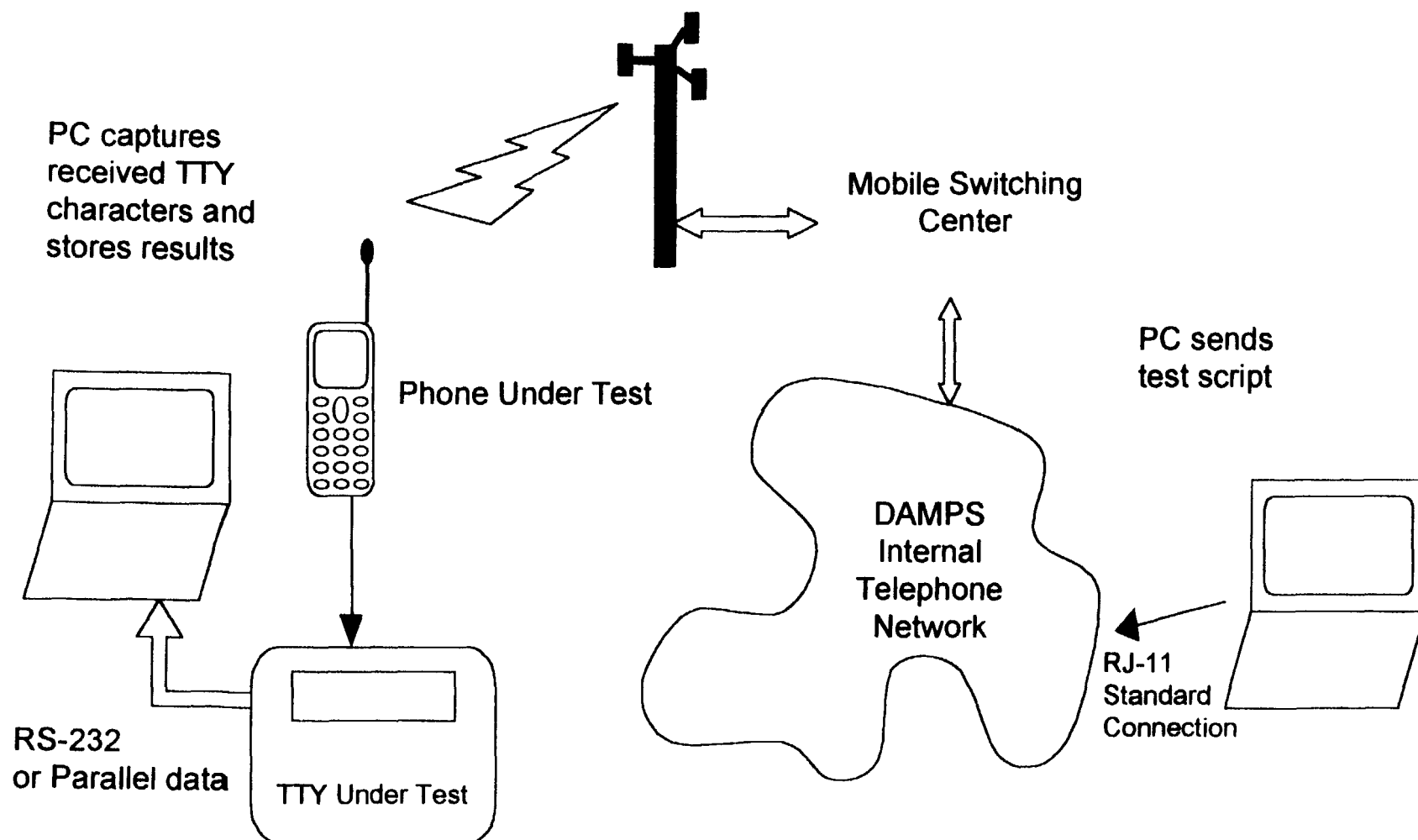
PC captures received TTY characters and stores results

Mobile Switching Center

Phone Under Test

PC sends test script

DAMPS Internal Telephone Network

RS-232 or Parallel data

TTY Under Test

RJ-11 Standard Connection

TTY / Digital Wireless

Test Data and Results

DAMPS 1900 ACELP

Using test script from L&W version 1.1 Copyright 1998
Device Tested: KF688 with Acoustic Handset

Uplink **HIGH** power (-75dBm), 0 % BER

- Percent Error (PCER)   =   ▮▮▮▮
- Total = 772, Correct 753, Added = 2, Missed = 8, Changed = 11
- Percent Error (TCER) =   1.45
- Total = 1106, Correct 1090, Added = 3, Missed = 9, Changed = 7

Downlink **HIGH** power (-75dBm), 0 % BER

- Percent Error (PCER)   =   ▮▮▮▮
- Total = 772, Correct 709, Added = 32, Missed = 31, Changed = 32
- Percent Error (TCER) =   4.05
- Total = 1086, Correct 1042, Added = 37, Missed = 39, Changed = 5

TTY / Digital Wireless
Test Data and Results
DAMPS 1900 ACELP
Using test script from L&W version 1.1 Copyright 1998
Device Tested: KF688 with Acoustic Handset

*Uplink **LOW** power, (-95dBm)*

● Unable to establish a Low power call test case without dropping the call completely.

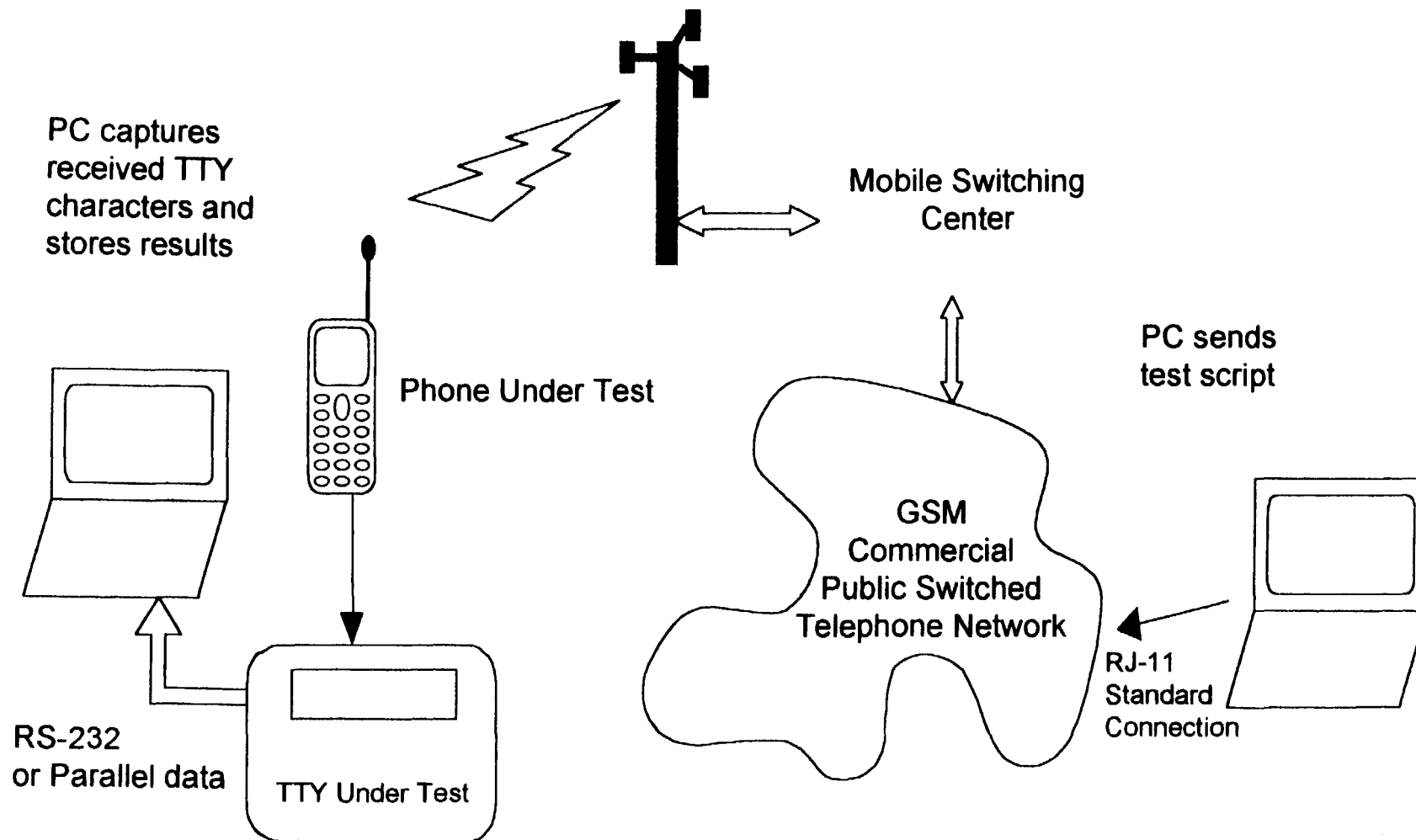*Downlink **LOW** power, (-95dBm)*

● Unable to establish a Low power call test case without dropping the call completely

GSM Mobile Termination Configuration

PC captures
received TTY
characters and
stores results

Mobile Switching
Center

Phone Under Test

PC sends
test script

GSM
Commercial
Public Switched
Telephone Network

RS-232
or Parallel data

TTY Under Test

RJ-11
Standard
Connection

TTY / Digital Wireless
Test Data and Results
GSM 1900 EFR
Using test script from L&W version 1.1 Copyright 1998
Device Tested: CF688 with Acoustic Handset

*Uplink **MEDIUM** power -91dBm (WIRED)*

- Percent Error (PCER)   =   0.26.
- Total = 772, Correct 770, Added = 0, Missed = 0, Changed = 2
- Percent Error (TCER) =   0.18
- Total = 1118, Correct 1116, Added = 0, Missed = 0, Changed = 2

*Downlink **MEDIUM** power -91dBm (WIRED)*

- Percent Error (PCER)   =   0.78
- Total = 772, Correct 766, Added = 24, Missed = 3, Changed = 3
- Percent Error (TCER) =   0.54
- Total = 1120, Correct 1114, Added = 24, Missed = 3, Changed = 3

TTY / Digital Wireless
Test Data and Results
GSM 1900 EFR
Using test script from L&W version 1.1 Copyright 1998
Device Tested: CF688 with ⬛⬛⬛⬛⬛ Handset

Uplink **MEDIUM** power (Wireless, Commercial Network, moderate bumblebee

- Percent Error (PCER)   =   0.39
- Total = 772, Correct 769, Added = 0, Missed = 1, Changed = 2
- Percent Error (TCER) =   0:27
- Total = 1118, Correct 1115, Added = 0, Missed = 1, Changed = 2

TTY / Digital Wireless
Test Data and Results
GSM 1900 EFR
Using test script from L&W version 1.1 Copyright 1998
Device Tested: CF688 with Acoustic Handset

*Uplink **LOW** power (Wireless, Commercial Network, moderate bumblebee, 1 hand-off -95dBm to -103dBm, 0%-4% BER:*
- Percent Error (PCER)   =   4.66
- Total = 772, Correct 736, Added = 2, Missed = 22, Changed = 14
- Percent Error (TCER) =   3.08
- Total = 1103, Correct 1069, Added = 3, Missed = 26, Changed = 8

*Downlink **LOW** power (Wireless, Commercial Network, moderate bumblebee, 2 hand-offs -95dBm to -103dBm, 0%-4% BER*
- Percent Error (PCER)   =   9.20
- Total = 772, Correct 701, Added = 29, Missed = 33, Changed = 38
- Percent Error (TCER) =   5.61
- Total = 1088, Correct 1027, Added = 31, Missed = 40, Changed = 21

TTY / Digital Wireless
Conclusion

- Direct vs acoustic connection for the mobile to TTY provides some improvement to CER in the Lab environment.

- Analog and GSM transmission performed well in Lab environments

- Under simulated conditions, with minimal variables of BER, hand-offs, Commercial Networks,and power level, CER increased 10X

- TCER and PCER vs. power level do not appear to be the most useful metrics for comparing system performance.

Test Results

No.	Link	Technology	TTY	Phone	Rate	Envir	Set	Test	Technology	Vocoder	TCER	PCER
1	Uplink	AMPS	Ultratec	AF778	3/4	Lab	AC	Static	IS-19		0.00%	0.04%
2	Downlink	AMPS	Ultratec	AF778	3/4	Lab	AC	Static	IS-19		0.00%	0.00%
3	Uplink	AMPS	Ultratec	AF778	3/4	Lab	DC	Static	IS-19		0.00%	0.04%
4	Downlink	AMPS	Ultratec	AF778	3/4	Lab	DC	Static	IS-19		0.00%	0.00%
5	Uplink	AMPS	Mobility	AF778	3/4	Lab	DC	Static	IS-19		0.08%	0.26%
6	Downlink	AMPS	Mobility	AF778	3/4	Lab	DC	Static	IS-19		0.02%	0.02%
7	Uplink	GSM1900	Mobility	CF688	3/4	Lab	DC	Static	IS-136	ACELP	0.78%	1.47%
8	Downlink	GSM1900	Mobility	CF688	3/4	Lab	DC	Static	IS-136	ACELP	1.13%	2.23%
9	Uplink	TDMA 800	Mobility	KF688	3/4	Lab	DC	Static	IS-136	VSELP	2.01%	3.61%
10	Downlink	TDMA 800	Mobility	KF688	3/4	Lab	DC	Static	IS-136	VSELP	0.19%	0.50%
11	Uplink	TDMA 1900	Mobility	KF688	3/4	Lab	DC	Static	IS-136	ACELP	1.33%	2.70%
12	Downlink	TDMA 1900	Mobility	KF688	3/4	Lab	DC	Static	IS-136	ACELP	0.29%	0.50%

Test Results

No.	Link	Technology	TTY	Phone	Rate	Envir	Set	Power	Network	Variables	TCER	PCER
13	Uplink	AMPS	Ultratec	AF778	Full	Lab	AC	High	Commercial		0.54%	0.78%
14	Downlink	AMPS	Ultratec	AF778	Full	Lab	AC	High	Commercial		0.36%	0.65%
15	Uplink	AMPS	Ultratec	AF778	Full	Lab	AC	Low	Commercial		0.18%	0.26%
16	Downlink	AMPS	Ultratec	AF778	Full	Lab	AC	Low	Commercial		2.90%	5.18%
17	Uplink	DAMPS 1900	Ultratec	KF688	Full	Lab	AC	High	Internal	0-BER	1.89%	4.40%
18	Downlink	DAMPS 1900	Ultratec	KF688	Full	Lab	AC	High	Internal	0-BER	1.45%	2.46%
19	Uplink	GSM1900	Ultratec	CF688	Full	Lab	AC	Medium	Internal	0-BER	0.18%	0.26%
20	Downlink	GSM1900	Ultratec	CF688	Full	Lab	AC	Medium	Internal	0-BER	0.54%	0.78%
21	Uplink	GSM1900	Ultratec	CF688	Full	Lab	AC	Medium	Commercial	0-BER	0.27%	0.39%
22												
23	Uplink	GSM1900	Ultratec	CF688	Full	Lab	AC	Low	Commercial	4 ber, 1HO	3.08%	4.66%
24	Downlink	GSM1900	Ultratec	CF688	Full	Lab	AC	Low	Commercial	4 ber,2HO	5.61%	9.20%

Test Results Comparison

No.	Link	Technology	Phone	Rate	Pwr	Network	Variables	TCER	PCER
1 v 13	Uplink	AMPS	AF778	3/4 v Full	H / H	Commercial		0.00 v 0.54%	0.04 v .78%
2 v 14	Downlink	AMPS	AF778	3/4 v Full	H / H	Commercial		0.00 v 0.36%	0.00 v 0.65%
3 v 15	Uplink	AMPS	AF778	3/4 v Full	H / L	Commercial		0.00 v 0.18%	0.04 v 0.26%
4 v 16	Downlink	AMPS	AF778	3/4 v Full	H / L	Commercial		0.00 v 2.9%	0.00 v 5.18%
7 v 19	Uplink	GSM1900	CF688	3/4 v Full	H / M	Comm v Inter	0-BER	.78 v 1.89%	1.47 v .26%
8 v 20	Downlink	GSM1900	CF688	3/4 v Full	H / M	Comm v Inter	0-BER	1.13 v 0.54%	2.23 v 0.78%
v 23	Uplink	GSM1900	CF688	v Full	/ L	Commercial	4 ber, 1HO	3.08%	4.66%
v 24	Downlink	GSM1900	CF688	v Full	/ L	Commercial	4 ber, 2HO	5.61%	9.20%
11 v 17	Uplink	DAMPS1900	KF688	3/4 v Full	H / H	Internal	0-BER	1.33 v 1.89%	2.70 v 4.40%
12 v 18	Downlink	DAMPS1900	KF688	3/4 v Full	H / H	Internal		.29 v 1.45%	0.5 v 2.46%